SCIENCE

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*THE PROBLEMS OF ASTRONOMY.**

ASSEMBLED, as we are, to dedicate a new institution to the promotion of our knowledge of the heavens, it appeared to me that an appropriate and interesting subject might be the present and future problems of astronomy. Yet it seemed, on further reflection, that, apart from the difficulty of making an adequate statement of these problems on such an occasion as the present, such a wording of the theme would not fully express the idea which I wish to convey. The so-called problems of astronomy are not separate and independent, but are rather the parts of one great problem, that of increasing our knowledge of the universe in its widest extent. Nor is it easy to contemplate the edifice of astronomical science as it now stands, without thinking of the past as well as of the present and future. The fact is that our knowledge of the universe has been in the nature of a slow and gradual evolution, commencing at a very early period in human history, and destined to go forward without stop, as we hope, so long as civilization shall endure. The astronomer of every age has built on the foundations laid by his predecessors, and his work has always formed, and must ever form, the base on which his successors shall build. The astronomer of to-day may look

*An address given by Professor Simon Newcomb at the dedication of the Flower Observatory, University of Pennsylvania, May 12, 1897.

back upon Hipparchus and Ptolemy as the earliest ancestors of whom he has positive knowledge. He can trace his scientific descent from generation to generation, through the periods of Arabian and mediæval science, through Copernicus, Kepler, Newton, La Place and Herschel, down to the present time. The evolution of astronomical knowledge, generally slow and gradual, offering little to excite the attention of the public, has yet been marked by two cataclysms. One of these is seen in the grand conception of Copernicus that this earth on which we dwell is not a globe fixed in the center of the universe, but is simply one of a number of bodies, turning on their own axes and at the same time moving around the sun as a center. It has always seemed to me that the real significance of the heliocentric system lies in the greatness of this conception rather than in the fact of the discovery itself. There is no figure in astronomical history which may more appropriately claim the admiration of mankind through all time than that of Copernicus. Scarcely any great work was ever so exclusively the work of one man as was the heliocentric system the work of the retiring sage of Frauenburg. No more striking contrast between the views of scientific research entertained in his time and in ours can be seen than that seen in the fact that, instead of claiming credit for his great work, he deemed it rather necessary to apologize for it and, so far as possible, to attribute his ideas to the ancients.

A century and a half after Copernicus followed the second great step, that taken by Newton. This was nothing less than showing that the seemingly complicated and inexplicable motions of the heavenly bodies were only special cases of the same kind of motion, governed by the same forces, that we see around us whenever a stone is thrown by the hand or an apple falls to the ground. The actual motions of the heavens and the laws which govern them being known, man had the key with which he might commence to unlock the mysteries of the universe.

When Huyghens, in 1656, published his *Systema Saturnium*, where he first set forth the mystery of the rings of Saturn, which, for nearly half a century, had perplexed telescopic observers, he prefaced it with a remark that many, even among the learned, might condemn his course in devoting so much time and attention to matters far outside the Earth, when he might better be studying subjects of more concern to humanity. Notwithstanding that the inventor of the pendulum clock was, perhaps, the last astronomer against whom a neglect of things terrestrial could be charged, he thought it necessary to enter into an elaborate defense of his course in studying the heavens. Now, however, the more distant objects are in space—I might almost add the more distant events are in time—the more they excite the attention of the astronomer, if only he can hope to acquire positive knowledge about them. Not, however, because he is more interested in things distant than in things near, but because thus he may more completely embrace in the scope of his work the beginning and the end, the boundaries of all things, and thus, indirectly, more fully comprehend all that they include. From his standpoint

> "All are but parts of one stupendous whole,
> Whose body nature is and God the soul."

Others study nature and her plans as we see them developed on the surface of this little planet which we inhabit; the astronomer would fain learn the plan on which the whole universe is constructed. The magnificent conception of Copernicus is, for him, only an introduction to the yet more magnificent conception of infinite space containing a collection of bodies which we call

the visible universe. How far does this universe extend? What are the distances and arrangements of the stars? Does the universe constitute a system? If so, can we comprehend the plan on which this system is formed, of its beginning and of its end? Has it bounds outside of which nothing exists but the black and starless depths of infinity itself? Or are the stars we see simply such members of an infinite collection as happen to be the nearest our system? A few such questions as these we are perhaps beginning to answer; but hundreds, thousands, perhaps even millions of years may elapse without our reaching a complete solution. Yet the astronomer does not view them as Kantian antinomies, in the nature of things insoluble, but as questions to which he may hopefully look for at least a partial answer.

The problem of the distances of the stars is of peculiar interest in connection with the Copernican system. The greatest objection to this system, which must have been more clearly seen by astronomers themselves than by any others, was found in the absence of any apparent parallax of the stars. If the earth performed such an immeasurable circle around the sun as Copernicus maintained, then, as it passed from side to side of its orbit, the stars outside the solar system must appear to have a corresponding motion in the other direction, and thus to swing back and forth as the earth moved in one and the other direction. The fact that not the slightest swing of that sort could be seen was, from the time of Ptolemy, the basis on which the doctrine of the earth's immobility rested. The difficulty was simply ignored by Copernicus and his immediate successors. The idea that Nature would not squander space by allowing immeasurable stretches of it to go unused seems to have been one from which mediæval thinkers could not entirely break away. The consideration that there could be no need of any such economy, because the supply was infinite, might have been theoretically acknowledged, but was not practically felt. The fact is that magnificent as was the conception of Copernicus, it was dwarfed by the conception of stretches from star to star so vast that the whole orbit of the earth was only a point in comparison.

An indication of the extent to which the difficulty thus arising was felt is seen in the title of a book published by Horrebow, the Danish astronomer, some two centuries ago. This industrious observer, one of the first who used an instrument resembling our meridian transit of the present day, determined to see if he could find the parallax of the stars by observing the intervals at which a pair of stars in oppposite quarters of the heavens crossed his meridian at opposite seasons of the year. When, as he thought, he had won success he published his observations and conclusions under the title of '*Copernicus Triumphans*.' But alas! the keen criticism of his contemporaries showed that what he supposed to be a swing of the stars from season to season arose from a minute variation in the rate of his clock, due to the different temperatures to which it was exposed during the day and the night. The measurement of the distance even of the nearest stars evaded astronomical research, until Bessel and Struve arose in the early part of the present century.

On some aspects of the problem of the extent of the universe light is being thrown even now. Evidence is gradually accumulating which points to the probability that the successive orders of smaller and smaller stars, which our continually increasing telescopic power brings into view, are not situated at greater and greater distances, but that we actually see the boundary of our universe. This indication lends a peculiar interest to various questions growing out of the motions of the stars. Quite pos-

sibly the problem of these motions will be the great one of the future astronomer. Even now it suggests thoughts and questions of the most far-reaching character.

I have seldom felt a more delicious sense of repose than when crossing the ocean during the summer months I sought a place where I could lie alone on the deck, look up at the constellations, with *Lyra* near the zenith, and, while listening to the clank of the engine, try to calculate the hundreds of millions of years which would be required by our ship to reach the star α Lyræ if she could continue her course in that direction without ever stopping. It is a striking example of how easily we may fail to realize our knowledge when I say that I have thought many a time how deliciously one might pass those hundred millions of years in a journey to the star α Lyræ, without its occurring to me that we are actually making that very journey at a speed compared with which the motion of a steamship is slow indeed. Through every year, every hour, every minute, of human history from the first appearance of man on the earth, from the era of the builders of the Pyramids, through the times of Cæsar and Hannibal, through the period of every event that history records, not merely our earth, but the sun and the whole solar system with it, have been speeding their way toward the star of which I speak on a journey of which we know neither the beginning nor the end. During every clock-beat through which humanity has existed it has moved on this journey by an amount which we cannot specify more exactly than to say that it is probably between five and nine miles per second. We are at this moment thousands of miles nearer to α Lyræ than we were a few minutes ago when I began this discourse, and through every future moment, for untold thousands of years to come, the earth and all there is on it will be nearer to α Lyræ, or nearer to the place where that star now is, by hundreds of miles for every minute of time come and gone. When shall we get there? Probably in less than a million years, perhaps in half a million. We cannot tell exactly, but get there we must if the laws of nature and the laws of motion continue as they are. To attain to the stars was the seemingly vain wish of the philosopher, but the whole human race is, in a certain sense, realizing this wish as rapidly as a speed of six or eight miles a second can bring it about.

I have called attention to this motion because it may, in the not distant future, afford the means of approximating to a solution of the problem already mentioned, that of the extent of the universe. Notwithstanding the success of astronomers during the present century in measuring the parallax of a number of stars, the most recent investigations show that there are very few, perhaps hardly more than a score of stars of which the parallax, and therefore the distance, has been determined with any approach to certainty. Many parallaxes, determined by observers about the middle of the century, have had to disappear before the powerful tests applied by measures with the heliometer; others have been greatly reduced, and the distances of the stars increased in proportion. So far as measurement goes, we can only say of the distances of all the stars, except the few whose parallaxes have been determined, that they are immeasurable. The radius of the earth's orbit, a line more than ninety millions of miles in length, not only vanishes from sight before we reach the distance of the great mass of stars, but becomes such a mere point that, when magnified by the powerful instruments of modern times, the most delicate appliances fail to make it measurable. Here the solar motion comes to our help. This motion, by which, as I have said, we are carried unceasingly

through space, is made evident by a motion of most of the stars in the opposite direction, just as, passing through a country on a railway, we see the houses on the right and on the left being left behind us. It is clear enough that the apparent motion will be more rapid the nearer the object. We may, therefore, form some idea of the distance of the stars when we know the amount of the motion. It is found that, in the great mass of stars of the sixth magnitude, the smallest visible to the naked eye, the motion is about three seconds per century. As a measure thus stated does not convey an accurate conception of magnitude to one not practiced in the subject, I would say that, in the heavens, to the ordinary eye, a pair of stars will appear single unless they are separated by a distance of 150 or 200 seconds. Let us then imagine ourselves looking at a star of the sixth magnitude, which is at rest while we are carried past it with the motion of six or eight miles per second which I have described. Mark its position in the heavens as we see it to-day; then let its position again be marked 5,000 years hence. A good eye will just be able to perceive that there are two stars marked instead of one. The two would be so close together that no distinct space between them could be perceived by unaided vision. It is due to the magnifying power of the telescope, enlarging such small apparent distances, that the motion has been determined in so small a period as the 150 years during which accurate observations of the stars have been made.

The motion just described has been fairly well determined for what astronomically speaking are the brighter stars, that is to say those visible to the naked eye. But how is it with the millions of faint telescopic stars, especially those which form the cloud masses of the Milky Way? The distance of these stars is undoubtedly greater, and the apparent motion is, therefore, smaller. Accurate observations upon such stars have been commenced only recently, so that we have not yet had time to determine the amount of the motion. But the indication seems to be that it will prove quite a measurable quantity, and that before the twentieth century has elapsed it will be determined for very much smaller stars than those which have heretofore been studied. A photographic chart of the whole heavens is now being constructed by an association of observatories in some of the leading countries of the world. I cannot say all the leading countries, because then we should have to exclude our own, which, unhappily, has taken no part in this work. At the end of the twentieth century we may expect that the work will be repeated. Then, by comparing the charts, we shall see the effect of the solar motion and, perhaps, get new light upon the problem in question.

Closely connected with the problem of the extent of the universe is another which appears, for us, to be insoluble because it brings us face to face with infinity itself. We are familiar enough with eternity, or, let us say, the millions or hundreds of millions of years which geologists tell us must have passed while the crust of the earth was assuming its present form, our mountains being built, our rocks consolidated, and successive orders of animals coming and going. Hundreds of millions of years is, indeed, a long time, and yet, when we contemplate the changes supposed to have taken place during that time, we do not look out on eternity itself, which is veiled from our sight, as it were, by the unending succession of changes that mark the progress of time. But in the motions of the stars we are brought face to face with eternity and infinity, covered by no veil whatever. It would be bold to speak dogmatically on a subject where the springs of

being are so far hidden from mortal eyes as in the depths of the universe. But, without declaring its positive certainty, it must be said that the conclusion seems unavoidable that a number of stars are moving with a speed such that the attraction of all the bodies of the universe could never stop them. One such case is that of Arcturus, the bright reddish star familiar to mankind since the days of Job, and visible near the zenith on the clear evenings of May and June. Yet another case is that of a star known in astronomical nomenclature as 1830 Groombridge, which exceeds all others in its angular proper motion, as seen from the earth. We should naturally suppose that it seems to move so fast because it is near us. But the best measurements of its parallax seem to show that it can scarcely be less than two million times the distance of the earth from the sun, while it may be much greater. Accepting this result, its velocity cannot be much less than 200 miles per second, and may be much more. With this speed it would make the circuit of our globe in two minutes, and had it gone round and round in our latitudes we should have seen it fly past us a number of times since I commenced this discourse. It would make the journey from the earth to the sun in five days. If it is now near the center of our system it would probably reach its confines in a million of years. So far as our knowledge of nature goes, there is no force in nature which would ever have set it in motion, and no force which can ever stop it. What, then, was the history of this star, and if there are planets circulating around, what the experience of beings who may have lived on those planets during the ages which geologists and naturalists assure us our earth has existed? Did they see, at night, only a black and starless heaven? Was there a time when, in that heaven, a small faint patch of light began gradually to appear? Did that patch of light grow larger and larger as million after million of years elapsed? Did it at last fill the heavens and break up into constellations as we now see them? As millions more of years elapse will the constellations gather together in the opposite quarter, and gradually diminish to a patch of light as the star pursues its irresistible course of 200 miles per second through the wilderness of space, leaving our universe farther and farther behind it, until it is lost in the distance? If the conceptions of modern science are to be considered as good for all time, a point on which I confess to a large measure of scepticism, then these questions must be answered in the affirmative.

Intimately associated with these problems is that of the duration of the universe in time. The modern discovery of the conservation of energy has raised the question of the period during which our sun has existed and may continue in the future to give us light and heat. Modern science tells us that the quantity of light and heat which can be stored in it is necessarily limited, and that, when radiated as the sun radiates, the supply must in time be exhausted. A very simple calculation shows that were there no source of supply the sun would be cooled off in three or four thousand years. Whence, then, comes the supply? During the past thirty years the source has been sought for in a hypothetical contraction of the sun itself. True, this contraction is too small to be observed; several thousand years must elapse before it can be measurable with our instruments. Granting that this is and always has been the sole source of supply, a simple calculation shows that the sun could scarcely have been giving its present amount of heat for more than twenty or thirty millions of years. Before that time the earth and the sun must have formed one body, a great nebula, by the condensation of which both are supposed to have been formed. But

the geologists tell us that the age of the earth is to be reckoned by hundreds of millions of years. Thus arises a question to which physical science has not been able to give an answer.

The problems of which I have so far spoken are those of what may be called the older astronomy. If I apply this title it is because that branch of the science to which the spectroscope has given birth is often called the new astronomy. It is commonly to be expected that a new and vigorous form of scientific research will supersede that which is hoary with antiquity. But I am not willing to admit that such is the case with the old astronomy, if old we may call it. It is more pregnant with future discoveries to-day than it ever has been, and it is more disposed to welcome the spectroscope as a useful hand-maid, which may help it on to new fields, than it is to give way to it. How useful it may thus become has been recently shown by a Dutch astronomer, who finds that the stars having one type of spectrum belong mostly to the Milky Way, and are farther from us than the others.

In the field of the newer astronomy perhaps the most interesting work is that associated with comets. It must be confessed, however, that the spectroscope has rather increased than diminished the mystery which, in some respects, surrounds the constitution of these bodies. The older astronomy has satisfactorily accounted for their appearance, and we might also say for their origin and their end, so far as questions of origin can come into the domain of science. It is now known that comets are not wanderers through the celestial spaces from star to star, but must always have belonged to our system. But their orbits are so very elongated that thousands, or even hundreds of thousands, of years are required for a revolution. Sometimes, however, a comet passing near to Jupiter is so fascinated by that planet that, in its vain attempts to follow it, it loses so much of its primitive velocity as to circulate around the sun in a period of a few years, and thus to become, apparently, a new member of our system. If the orbit of such a comet, or in fact of any comet, chances to intersect that of the earth, the latter in passing the point of intersection encounters minute particles which causes a meteoric shower. The great showers of November, which occur three times in a century and were well known in the years 1866–67, may be expected to reappear about 1900, after the passage of a comet which, since 1866, has been visiting the confines of our system, and is expected to return about two years hence.

But all this does not tell us much about the nature and make-up of a comet. Does it consist of nothing but isolated particles, or is there a solid nucleus, the attraction of which tends to keep the mass together? No one yet knows. The spectroscope, if we interpret its indications in the usual way, tells us that a comet is simply a mass of hydro-carbon vapor, shining by its own light. But there must be something wrong in this interpretation. That the light is reflected sunlight seems to follow necessarily from the increased brilliancy of the comet as it approaches the sun and its disappearance as it passes away.

Great attention has recently been bestowed upon the physical constitution of the planets and the changes which the surfaces of those bodies may undergo. In this department of research we must feel gratified by the energy of our countrymen who have entered upon it. Should I seek to even mention all the results thus made known, I might be stepping on dangerous ground, as many questions are still unsettled. While every astronomer has entertained the highest admiration for the energy and enthusiasm shown by Mr. Percival

Lowell in founding an observatory in regions where the planets can be studied under the most favorable conditions, they cannot lose sight of the fact that the ablest and most experienced observers are liable to error when they attempt to delineate the features of a body 50 or 100 million miles away through such a disturbing medium as our atmosphere. Even on such a subject as the canals of Mars doubts may still well be felt. That certain markings to which Schiaperelli gave the name of canals exist, few will question. But it may be questioned whether these markings are the fine sharp uniform lines found on Schiaparelli's map and delineated in Mr. Lowell's beautiful book. It is certainly curious that Barnard at Mount Hamilton, with the most powerful instrument and under the most favorable circumstances, does not see these markings as canals.

I can only mention among the problems of the spectroscope the elegant and remarkable solution of the mystery surrounding the rings of Saturn, which has been effected by Keeler at Allegheny. That these rings could not be solid has long been a conclusion of the laws of mechanics, but Keeler was the first to show that they must consist of separate particles, because the inner portions revolve more rapidly than the outer. The question of the atmosphere of Mars has also received an important advance by the work of Campbell at Mount Hamilton. Although it is not proved that Mars has no atmosphere, for the existence of some atmosphere can scarcely be doubted, yet the Mt. Hamilton astronomer seems to have shown, with great conclusiveness, that it is so rare as not to produce any sensible absorption of the solar rays.

I have left an important subject for the close. It belongs entirely to the older astronomy, and it is one with which I am glad to say this observatory is expected to especially concern itself. I refer to the question of the variation of latitudes, that singular phenomenon scarcely suspected ten years ago, but brought out by observations in Germany during the past eight years, and reduced to law with such brilliant success by our own Chandler. The north pole is not a fixed point on the earth's surface, but moves around in rather an irregular way. True, the motion is small; a circle of sixty feet in diameter will include the pole in its widest range. This is a very small matter so far as the interests of daily life are concerned. But it is very important to the astronomer. It is not simply a motion of the pole of the earth, but a wabbling of the solid earth itself. No one knows what conclusions of importance to our race may yet follow from a study of the stupendous forces necessary to produce even this slight motion.

The director of this new observatory has already distinguished himself in the delicate and difficult work of investigating this motion, and I am glad to know that he is continuing the work here with one of the finest instruments ever used in it, a splendid product of American mechanical genius. I can assure you that astronomers the world over will look with the greatest interest for Professor Doolittle's success in the arduous task he has undertaken.

There is one question connected with these studies of the universe on which I have not touched, and which is, nevertheless, of transcendent interest. What sort of life, spiritual and intellectual, exists in distant worlds? We cannot for a moment suppose that our own little planet is the only one throughout the whole universe on which may be found the fruits of civilization, warm firesides, friendship, the desire to penetrate the mysteries of creation. And yet, this question is not to-day a problem of astronomy, nor can we see any prospect that it ever will be, for the simple reason that science affords us no hope of

an answer to any question that we may send through the fathomless abyss. When the spectroscope was in its infancy it was suggested that possibly some difference might be found in the rays reflected from living matter, especially from vegetation, that might enable us to distinguish them from rays reflected by matter not endowed with life. But this hope has not been realized, nor does it seem possible to realize it. The astronomer cannot afford to waste his energies on hopeless speculation about matters of which he cannot learn anything, and he therefore leaves this question of the plurality of worlds to others who are as competent to discuss it as he is. All he can tell the world is:

> He who through vast immensity can pierce,
> See worlds on worlds compose one universe;
> Observe how system into system runs,
> What other planets circle other suns,
> What varied being peoples every star,
> May tell why Heaven has made us as we are.

SIMON NEWCOMB.

WASHINGTON, D. C.

THE RECENT VISIT OF SIR ARCHIBALD GEIKIE.

AMERICAN geology has been greatly benefited and stimulated by visits from distinguished European scientists, since the early part of the present century. All will recall at once Bakewell's observations on the recession of Niagara; Lyell's two visits, with the four volumes of 'Travels in America' that resulted, and that helped so much to establish a good correlation between many of our formations and those of Europe; von Richthofen's four years on the Pacific coast, and Credner's four years in the East; Posepny's travels in our mining districts; vom Rath's visits to mineral localities, and Geikie's excursions across the lava fields of the Snake River country. After an interval of eighteen years, the honor of again entertaining the distinguished Director of the British Geological Survey has fallen to American geologists, and has proved to be an occasion of exceptional interest and importance.

Some months ago Sir Archibald was invited by the authorities at the Johns Hopkins University to come to Baltimore and open the course of lectures in geology, made possible by a foundation established by Mrs. George Huntington Williams, in memory of her husband, the late, greatly lamented professor at Johns Hopkins. The purpose of the foundation is to support an annual course of lectures in geology which are to be given alternately by European and American geologists of distinction. No more fitting choice for the first series could have been made than that of Sir Archibald Geikie, to whose cosmopolitan sympathies, as shown in his 'textbook,' geologists everywhere owe so great a debt.

Sir Archibald reached New York April 17th, and on April 19th was given a reception by the New York Academy of Sciences, as described in an earlier page of SCIENCE (p. 702). Geologists from many institutions outside of New York united with the members of the Academy to make the welcome a cordial and significant one.

On Wednesday, April 21st, Sir Archibald began, at the Johns Hopkins University, the course of lectures which was the main object of his visit. The subject chosen was 'The Founders of Geology,' and in his treatment of the theme the lecturer sketched the rise of geological conceptions among the ancient cosmogonists, tracing their gradual though slow evolution through the middle ages, and their vigorous development at the opening of the present century. Exhaustive studies have been made by Sir Archibald upon these special subjects, and much new light has been thrown by them upon the true relations of modern systems of thought to the work of the pioneers in this field a hundred years and less ago. The lectures will ultimately be published, and space is